International Journal of Information Management 37 (2017) 505–519

Contents lists available at ScienceDirect

International Journal of Information Management

journal homepage: www.elsevier.com/locate/ijinfomgt

GAWA – Manager for accessibility Wayfinding apps

M.C. Rodriguez-Sanchez[a,*], Juan Martinez-Romo[b]

[a] Electronics Department, Universidad Rey Juan Carlos, C\ Tulipán, s/n. Madrid, Spain
[b] NLP & IR Group, Departamento de Lenguajes y Sistemas Informáticos, UNED, C\ Juan del Rosal, 16. Madrid, Spain

ARTICLE INFO

Keywords:
Web technologies
Accessibility
Disability
Collaborative process integration
Semantic web service

ABSTRACT

With this work, we propose and validate a new service system in the context of Wayfinding services to improve the SmartCities mechanism: smart mobility, smart people, smart governance and smart living services. Steering and navigation tasks through an environment constitute an essential activity in our daily lives. They have a high degree of practical value in a variety of domains, such as public area design, architectural Wayfinding, geo-positioning and navigation, as well as urban planning and environmental design. At times, people with a visual impairment may also have problems in navigating autonomously and without personal assistance, especially in unknown environments (outdoor and indoor) using a smartphone. There could also be emergency situations in which the receiving of information in real time could be crucial. People with motor disabilities usually need information to avoid environments with obstacles, to arrive at a target or to manage touchscreens in daily activities and different environments. The use of landmarks is therefore vitally important in human navigation. Wayfinding systems must change, given that according to the United Nations (UN) Development Program, people with a disability represent around 10% of the world's population, which is approximately 650 million people. Additionally, according to the World Health Organization, the world's population of people 60 years of age and older has doubled since 1980 and is predicted to reach 2 billion by 2050. Most Wayfinding applications in the Smartphone market suffer from at least one of the following problems: the information is not dynamic, the design is not universal or the interface is not adapted to different users and preferences. Accordingly, apps do not currently have a universal design. The GAWA platform provides a universal and accessible solution to manage Wayfinding applications that focuses on people with a disability in outdoor and indoor environments in Smartcities. According to the results, the platform could be used for performing activities in their daily lives.

1. Introduction

Cloud technology has emerged with the expansion of the Internet of Things (Sheng et al., 2013). Today many infrastructures, platforms, and software mobile applications are offered as services using cloud technology. This technology is oriented towards facilitating the access and processing of information and services anywhere. It is being expanded to the new concept of intelligent cities: the SmartCities (Caragliu, Del Bo, & Nijkamp, 2011). These cities are focused on solving different problems that currently exist in modern cities, such as the management and monitoring of waste, traffic monitoring, mobility, energy, water, education, telemedicine and tourism, amongst others (Su, Li, & Fu, 2011). According to (Giffinger et al., 2007), Smartcities must have six characteristics to become smart: a smart economy, smart governance, smart people, smart mobility, a smart environment and smart living. In this work, we propose and validate a new service system in the context of Wayfinding services (Li, 2006) to improve the mechanism for smart mobility, smart people, smart governance and smart living services: the GAWA system. Wayfinding services include location, adapted routes and navigation tools for different people in the city. The people (end users) can benefit from this kind of service using the Wayfinding applications for Smartphones or Wearable Devices.

In fact, steering and navigation tasks through an environment constitute an essential activity in our daily lives. In recent times, many people use the smartphone to navigate through different parts of a city, village, hospital or museum. In the field of Wayfinding systems, there are four main challenges: outdoor navigation, indoor navigation, the accessible use of mobile navigation applications, the existence of an accessible database with information on Points of Interest and routes, as well as the management of both applications and the database. This management must be possible by people with and without a disability, in order to provide universal access.

With the success of smartphones, outdoor and indoor navigation systems for pedestrians have reached the end consumer market. Over

* Corresponding author.
E-mail addresses: cristina.rodriguez.sanchez@urjc.es (M.C. Rodriguez-Sanchez), juaner@lsi.uned.es (J. Martinez-Romo).

http://dx.doi.org/10.1016/j.ijinfomgt.2017.05.011
Received 16 November 2016; Accepted 21 May 2017

the last few years, a great deal of research has emerged to improve understanding of the pedestrian route selection. The development of pedestrian-navigation services calls for further research in order to improve the understanding of pedestrian space-temporal behavior. The main goals in the design of navigational tools are to ensure the efficiency of infrastructure and individual comfort and safety. This includes both individual benefits (such as walking efficiency, safety, and time-reduction) and the opportunity to control pedestrian movement and flow within an infrastructure or a local neighborhood to avoid obstructions and accident hazards. The application areas of pedestrian-navigation and information systems cover many different contexts. For instance, indoor navigation is a very important issue for Smartcities because when a pedestrian arrives at a destination by using outdoor navigation services, he/she often needs to enter a building and requires indoor navigation. For example, the use of mobile technologies in certain scenarios of outdoor navigation (Swierenga, Propst, Ismirle, Figlan, & Coursaris, 2014; Borràs, Moreno, & Valls, 2014) such as tourism has increased in the last couple of years. Other scenarios could be: business trips, recreational trips, rescue services and active aging. Active aging and personal navigation aid is oriented towards users with specific demands, such as people with a disability or the elderly.

For indoor applications, different location technologies are used to replace GPS (for example: infrared, ultrasonic, Bluetooth or Zigbee). In this way, the LBS (Location Based System) is a very important tool for the construction of navigation systems. Some studies have presented proposals for indoor environments (Millonig and Schechtner, 2007; Nasir, Lim, Nahavandi, & Creighton, 2014) with phones or smartphones. Systems without specific instrumentation for specific buildings − such as Google Indoor Maps − offer varying reliability. One of the advantages of the solution is that Google Indoor Maps does not need specific instrumentation for each building. However, it needs a cognitive as well as technical perspective and user characteristics and environmental properties must be appropriately modeled to capture phenomena of interests (Montello and Sas, 2006). Besides, there are several limitations related to user devices, free management of information, accessible information, adapted information and wireless signal in the environment. Another issue is that use is not available for outdoor environments at the same time.

Some proposals have emerged that combine outdoor and indoor environments (Gartner, Frank, & Retscher, 2004; Ficco, Palmieri, & Castiglione, 2014). However, they are partial solutions (a specific context or a specific profile of users). For location and navigation services, Smart-cities need to provide solutions for different environments and users. For instance, in a city there could be different users with different preferences, ages or disabilities. Despite the recent appearance of several outdoor and indoor navigation systems, there are still many people that cannot use them because of their lack of accessibility: people with a disability.

Many people with a disability usually looking for accessible and mobile information on cities plan their trips when they are visiting a new place or when they are starting a new job in a new city. The problems emerge due to the lack of autonomy in mobility and navigation services. Not many people with a disability choose to go to a museum/theater/job/university. We can imagine their vulnerability in a new city when visiting places of interest, new hotels or tourist routes. They may also have problems navigating autonomously and without personal assistance, especially in unknown environments. In these cases, questions may arise like: where is the traffic light, bus stop or a simple litterbin? Many applications only provide text, audio or map information. Moreover, the interfaces and information are not usually adapted to different users. People with a disability would be greatly assisted by accessible navigation systems. According to the United Nations Development Program, people with a disability represent around 15% of the world's population, about 650 million people. The disability could be a physical, sensorial or cognitive impairment. Additionally, according to the World Health Organization, the world's population of people 60 years of age and older has doubled since 1980 and is predicted to reach 2 billion by 2050. We should not overlook the fact that their partners often accompany them. All these people are potential end-users of Wayfinding services in Smart-cities.

According to (Giudice and Legge, 2008), one of the biggest challenges for independent living of the blind and the visually impaired is access to safe and efficient navigation. In order to navigate safely, blind people must know their own location and learn how to detect obstructions. For instance, they need to find curbs easily (outside buildings) or stairs (inside buildings), to understand and interpret traffic patterns or to find a bus. Besides, deaf people need to communicate with other users to ask for directions or receive alarms in emergency situations and people with motor disabilities usually need information to avoid environments with obstacles in order to reach a destination or to manage touchscreens in normal or emergency situations.

Over the last decade, many navigation and guidance applications have emerged for people with a disability, blind or people with motor disabilities. According to (Downs and Stea, 1977), a Wayfinding system must include four tasks: orientation, route planning, keeping on the right track and discovering the destination. Some works such as (Poláček, Grill, & Tscheligi, 2012) have applied this recommendation, but only for blind people. Therefore, there are more aspects to be considered when we develop a universal and accessible navigation system for people with different pReferences

1.1. State of the art

In this section, we present the state of the art in four fields that we consider essential for the performance of any Wayfinding system, as described in this paper: challenges in indoor and outdoor locations, interfaces adapted to disabled people, universal information management, strengths and contributions.

1.1.1. Challenges in indoor and outdoor locations

With the success of smartphones, navigation systems for pedestrians have reached the end consumer market. The use of mobile technologies in certain scenarios, such as tourism, has therefore increased in the last couple of years (Borràs et al., 2014). Tourism is an activity of great importance, both economically and in terms of the pleasure it gives to holidaymakers worldwide. This has led the emergence of the Wayfinding systems. Mobile devices are being aligned as a perfect technological ally to access information on different places. Moreover, in the last year, location techniques have improved in order to provide the basis for Wayfinding systems: the Global Positioning System (GPS) for outdoors; Bluetooth, NFC and QR-code for Indoor Location.

Examples of Wayfinding systems are navigation and guidance projects, in which information on the current location is displayed. There have also been studies on location, navigation, assistive guidance and implications specifically for the design of mobile technologies.

Compass (van Setten, Pokraev, & Koolwaaij, 2004) is a context-sensitive tourist guide for mobile phones, offering the user recommendations and services. Crumpet (Poslad et al., 2001) is a tourist guide for mobile phones and PDAs with GPS positioning that allows the user to recommend services with interactive maps online. Gulliver's Genie (O'Hare and O'Grady, 2003) provides an intelligent mobile travel guide using GPS to detect possible points of interest near its position and offer all the information to the tourist. The downside of these solutions is that they are not adapted to visually impaired users.

Other solutions provided by similar outdoor location systems are, for example, Microsoft's proposal for indoor spaces (Microsoft Research, 2017a, 2017b), which has a system known as "Indoor-GPS". There has also been research mainly to obtain positioning in indoor environments with the implementation of an inertial navigation system.

After obtaining the user's location by discovering Bluetooth or Wi-Fi access points, it is possible to approximate the movement by measuring the acceleration of the device at all times. There are also other studies such as (Tesoriero, Gallud, Lozano, & Penichet, 2008) using RFID (Radio Frequency Identification: storage and retrieval system of wireless data) to provide indoor location. Techniques such as reader bows and RFID tags are used to detect user movement through different sectors by reader bows and record its position.

1.1.2. Adapted interfaces for disabled people

When disabled people travel in a city, they usually need physical references or adapted information on their surroundings. While we acknowledge that progress on assistive technologies has ben achieved, users still face a number of problems when interacting with Smartphones and technologies. Most of the public information is in text panels, monitors or traffic signals and is not based on global accessibility criteria. This group of people cannot be informed instantaneously and is unaware of possibly dangerous situations. In conclusion, the rights and needs of these people are often overlooked.

Therefore, the majority of Wayfinding systems are not usable by all users: there still exist several barriers for the blind, deaf or physical disabled people. Therefore, the people with a disability that could benefit the most from the use of such systems are precisely those that experience the greatest difficulties when accessing tourism resources. Blind people do not receive the same information as normally sighted users. The physical impaired need to be guided through places without barriers.

In this respect, ICTs (Information and Communication Technologies) are becoming a medium providing important services at home or in public places. Technology in general and mobile devices in particular could be useful tools to increase the independence of the disabled. Assistive technology focuses on promoting greater functional independence for people with a disability (Oulasvirta, Tamminen, Roto, & Kuorelahti, 2005). For certain disabilities, the requirements for dual interface development must address the needs of target users, as well as their Personal Assistants. Computer access for disabled people has been a key issue for many years. Considerable work has been performed to make software systems more accessible (Fink, Kobsa, & Nill, 1999).

Some projects have proposed new input methods (Bonner, 2010). The interface layout and letter management can be edited to accommodate the user textbox based on user preferences (gesture approach or adapted notes are some examples). In (Oliveira, Guerreiro, Nicolau, Jorge, & Gonçalves, 2011), a proposal to identify and quantify the individual attributes that make a difference for blind users when interacting with a mobile touch screen is presented. The solution could be used in Wayfinding applications. AccesSights (Klante, Krösche, & Boll, 2004) are mobile tourist guides for the blind and visually impaired people. The user profile is used to display information adapted to the user. Another project that has been developed for applications that help the blind and visually impaired people to receive the same information is MoBIC (Brumitt, Meyers, Krumm, Kern, & Shafer, 2000). Yao-Jen et. al (Pielot, Poppinga, & Boll, 2005) describe the implementation of mobile social networks in collaboration with a supported employment program established for people with a severe mental illness. However, they are solutions only for outdoor environments.

With regard to indoor environments, we analyzed different works such as (Yayan, Akar, Inan, & Yazici, 2014). The first is a preliminary study to receive contextual information for blind people using beacons with a wireless connection. The second is oriented towards users in a wheelchair. AmbienNet architecture (Abascal, Boanil, Gardeazabal, Lafuente, & Salvador, 2009) was designed to allow structured context information to be shared by intelligent applications that support people with a disability or the elderly living alone. In a tourism context, there are several indoor applications, such as those for museums (Jain, 2014) which apply a guidance application for blind users. However, the problem with these projects is how to manage information and routes. Moreover, they only can apply the solution to indoor environments.

For both environments, Drishti (Ran, Helal, & Moore, 2004) is an integrated indoor and outdoor navigation service only for blind users. However, the system is very expensive. There are other technologies such as Bluetooth, Wi-Fi or NFC, which are more affordable. In addition, other users with different preferences or other sensorial, cognitive or physical capabilities cannot use the same interface.

There are navigation applications that offer audio feedback for Wayfinding applications. However, when the user is a deaf person, or in very noisy environments, the use of the audio channel requires headphones, which cut the user off from the environment, or speakers, which may be disturbing to others and/or embarrassing. The problems for deaf users have been analyzed in certain empirical good practice studies (Hersh, Ohene-Djan, & Naqvi, 2010). As a solution to these problems, the research of several groups has focused on the use of special tactile displays for navigation guidance support for mobile phones. Other recommended systems for deaf users to avoid noise problems are presented in (Mielke, Grunewald, & Bruck, 2013). Different requirements for suitable assistance devices have resulted from the analysis of this work.

Moreover, according to (García de Marina, Carro, & Haya, 2012), there are several studies focused on providing assistance to users with cognitive limitations when traveling. In (Fickas, Lemoncello, & Sohlberg, 2010), the study concludes that users with cognitive limitations have more difficulties when following a route because they have more frequent questions and need more trials and recalculations. However, there are solutions for outdoor environment.

The majority of solutions address a small number of disabled users and are usually fairly expensive due to the restricted customer base. It is easier and cheaper to deploy information services for people without a disability, whereas ICTs can create transparent environments for disabled people. Therefore, for many categories of disabled people, ICTs may even allow for a partial compensation of their disability or functional restrictions.

1.1.3. Disability: information and management

The building of an accessible Wayfinding application for Smartphones is a complex and time-consuming task. Some frameworks can provide support to simplify the development tasks and some aspects of application functionality. Some research does not consider architectural abstractions for user interface and Wayfinding management (Kramers, 2014). Most literature reports only on prototype systems and applications based on specific architectures without accessibility and universal design criteria. (Yuen, Lee, & Lam, 2014) proposes a model for a transportation station. USE-IT (Bonner, 2010) is a knowledge-based tool for automating the design of interactions at a physical level, so as to ensure accessibility to the target user interface by different user groups, including people with a disability.

European initiatives have therefore been created to be oriented towards accessibility, amongst which is the accessible-EU (Plataforma Accesible-EU, 2017), aimed at providing tools for standardization and modeling for issues of accessibility and software developed for disabled users. In addition, we have the AEGIS (AEGIS, 2017) and OASIS (OASIS, 2017) projects aimed at promoting technology and accessibility and, for example, thanks to OASIS, services are offered to promote personal autonomy through guidelines on mobility and exercises of social and professional integration.

ASK-IT (ASK-IT, 2017) is a geo-location services-oriented platform for places with tourist attractions. Other European initiatives that can be highlighted are the ENAT network (European Network Accessibility Tourism) (ENAT, 2017), focused on the promotion of tourism and accessibility. Among his proposals we highlight T-GuIDE (T-GuIDE, 2017), aimed at promoting social and professional integration of people with a disability. Also at a national level (Spain), the PREDIF (Predif, 2017) confederation provides a tool for access to tourist information, accessible via smartphone. In (Angin and Bhargava, 2011), the authors proposed a cloud platform to access location-specific information resources on the web only for blind users.

Another issue is the design of interfaces. The designers of user interfaces are usually people who have no visual impairment. Therefore, they have a limited understanding of how blind people's experiences with technology. It is important for designers to better understand how blind people actually use touch screens (Kane, Wobbrock, & Ladner, 2011). Furthermore, a designer who wishes to provide gestures in their applications must consider whether or not the gestures will be appropriate for blind users. Although blind people may use the same hardware as their sighted peers, it is possible that they will prefer to use different gestures, or perform the same gestures differently than sighted users. Sighted people perform gestures differently when they lack visual feedback (Tinwala and MacKenzie, 2010). The objective is to work on solutions to facilitate the generation of accessible applications and content by user interface designers. Moreover, user interface designers could be people with a disability. Therefore, a platform to solve these problems has to be universal (designers and end-users).

1.2. Strengths and contributions

The European Economic and Social Committee (CESE) welcomes the European Disability Strategy 2010–2020 (EED) to improve participation in cultural life, recreation, leisure and sport, monuments and sites of national cultural importance. Therefore, it is important to improve the Smartcity services for people with a disability. This paper focuses on aspects of improving accessible information, tailored routes and orientation for travelers along such multimodal journeys for people with a disability. In short, according to the state of the art, the problems relating to interfaces for Wayfinding/pedestrian navigation systems are:

Most Wayfinding applications for navigation assistance in the market have at least one of the following problems: the information is not accessible, the design is not universal or the interface is not adapted to different users and pReferences

· Although there are different applications for people with a disability, they are only partial solutions. There are different developments that are not complete for people with physical disabilities, people with cognitive impairments problems, blind users or deaf users. To find a universal design is the challenge at hand. Thus, the majority of interfaces do not have a universal and intuitive design.

- Most Wayfinding systems not are useful for people with a disability and without a disability at the same time, in indoor and outdoor environments.
- The information is presented to pedestrians via audio, visual or both systems. However, this communication may be unsuitable in many situations typically faced by pedestrians when navigating (for instance: noisy environments).
- There are several problems involved in the development and management of information accessible to Wayfinding applications. (De Oliveira, Bacha, Mnasser, & Abed, 2013) is a study on the adaptation of interfaces and information in the development of Wayfinding interaction systems. However, it does cater for people with a disability.

We propose a complete architecture to improve the management and deployment of accessible Wayfinding Services (for people with and without a disability). We call this proposal: the GAWA System. We have consider some of the issues in the development of this work previously introduced in (García de Marina et al., 2012).

Firstly, this proposal allows us to easily adapt the accessibility of the interfaces and the content of Wayfinding Services. These services have to be adapted to the constraints imposed by user capabilities (sensorial, cognitive and physical capabilities).

Secondly, it is important to collect information (general description, accessibility description, physical barriers and location) on the different Points of Interest (POIs) and Safety Points in a city: public or private buildings, universities, subways, transport, traffic jumps, pedestrian crosswalks, litterbins, etc. This information must be useful in order for all kinds of points to be geo-positioned in outdoor and indoor environments.

Thirdly, the GAWA must generate accessible Wayfinding applications for both indoor and outdoor guidance using the same application. It includes accessible information, tailored routes and landmarks oriented to facilitate access to different places in an environment, city or country. It is necessary to model zones within a map (streets, intersections, buildings, park areas, landmarks, etc.) amongst the POIs and Safety Points. In addition, the application can provide information and guidance in a normal situation (daily activities or tourism) and also in an emergency situation (for instance, accessible evacuation of a building). There is another specific feature for the generated Wayfinding application: it has to be operative irrespective of the network access and GPS information. To achieve this, we integrate devices for indoor location to solve the issue.

Fourthly, mobile phones, Smartphones and Wearables highlight another part of the heterogeneity problem. These devices are characterized by different restrictions relating to processing, memory, battery and communications bandwidth. The support of programming platforms changes from one device to another, which makes it difficult to adapt a single platform in the application development process. Although there are certain phones that are adapted to disabled people, all users want to buy trendy phones (Android, iOS, Nokia, etc.). Therefore, the GAWA should be a system capable of managing all platforms.

The fifth issue relates to the feasibility of the information. The systems have to have tools to record the paths followed by each user or validate paths proposed by accessibility and guidance experts.

Sixthly, in order to facilitate these requirements, there is an online tool in the GAWA (a GAWA web page) to facilitate the tasks for Wayfinding services anywhere and anytime. This tool does not require programming knowledge. It assists developers in the accessible Wayfinding application creation process, making the creation of user-focused applications easier to use and faster. It also allows management of the content, multimedia, audio and videos of the guides, based on accessibility criteria. Moreover, the web page has tools to manage tailored routes to avoid physical obstacles or accessibility problems in the environment using landmarks and multimodal information. This management is very important to support events, news, special activities or other issues in the different contexts of the applications.

Finally, we suggest that this kind of platforms could be a solution for smart-cities to improve the accessibility and universality of services and resources for public and private entities.

2. The gawa system

2.1. Description

In this paper we present a novel solution: the GAWA System. As mentioned above, it is oriented towards the construction, generating and management of accessible Wayfinding Services. These services include the management of content, information and mobile navigation applications (Wayfinding applications) for Smartcities, for people with and without a disability. The management of applications means that the system generates different Wayfinding applications with the GAWA information. In the following sections, we describe this process in more detail.

Our proposal consists in an effort to facilitate access to information by people with a disability their Smartphones in outdoor and indoor spaces. In addition, the proposed system architecture may help institutions to integrate accessibility information (museums, tourism office, universities, etc.) using mobile and wireless technologies. Furthermore, the accessible interfaces and functionalities of the GAWA facilitate the social and job market integration of people with a disability, accessible tourism and active aging. In this way, users can enjoy

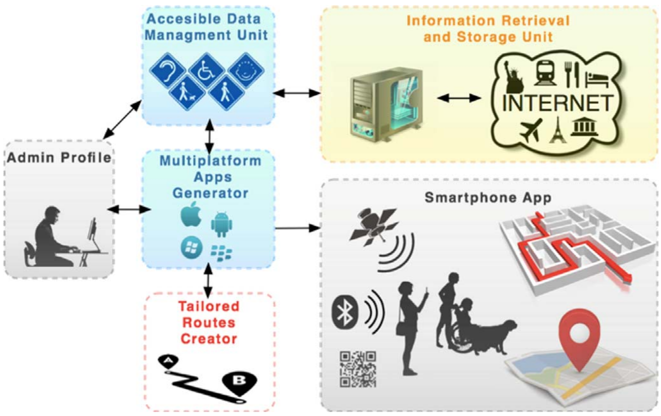

Fig. 1. GAWA Architecture, example with admin profile.

the basic services of a mobile phone and special Wayfinding applications in order to improve the access to information in different contexts. The application has been designed from a global accessibility perspective, which means that it can be used by anyone, with or without a disability. The proposal is therefore a scalable, sustainable and powerful way for Smartcities to include Wayfinding services.

2.2. Architecture

The architecture has been defined according the motivation of this proposal and the requirements described above (see Fig. 1). It consists of several units: "Accessible Data Management", "Information, Retrieval and Storage", "Multiplatform Apps Generator", "Tailored Routes Creator" and "Smartphone App". As described in the following subsection, there are different profiles:

2.2.1. Manager profiles of the GAWA system

Fig. 2 shows the two manager profiles of the Gawa System. Each user profile has a different type of access to the Architecture units. The first is the Information Management profile. It has access to the GAWA Website to use the "Information Management" tools. Currently, most services that generate applications for Wayfinding require the manager to generate or find the relevant information manually from different websites (for example: museums, tourists, cities, Wikipedia, dBPedia, Predif, etc.). We realized that it is necessary to automate these searching processes to facilitate and reduce the time required to collect this kind of information (POIs, safety points, landmarks and barriers). This profile can collect the information for Wayfinding systems using an "Information Retrieval" unit (Fig. 3).

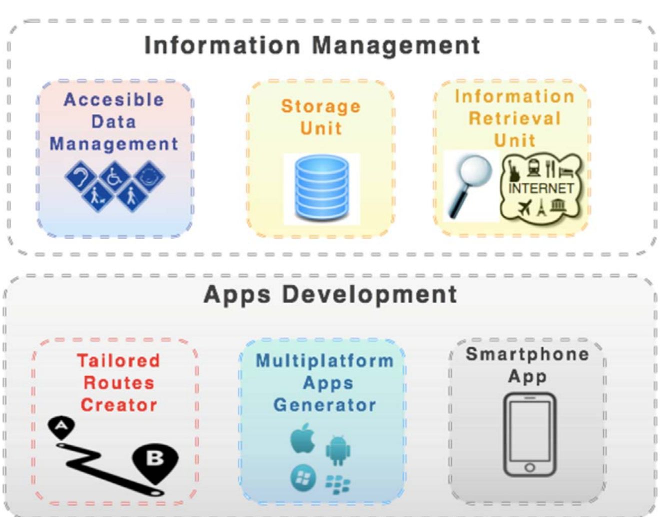

Fig. 2. GAWA user profiles.

It is important to provide user with this information in an easy and automatic way, based on accessibility criteria. Our online management system independently acquires the information and accessible parameters from websites (examples of use are Wikipedia, DBpedia, predif.org, etc.). This service could increase the capacity of public administrations for coaching a larger number of people and reduce current costs, pedestrian routing with physical references and obstacles, steering objectives for tourists and information management process time, using online access via a web portal. We have developed this service in order to deploy the platform in new environments (hospitals, conferences, congresses, cities, other universities, safety programs, …).

The second is the Apps Development Management profile. This profile can generate Wayfinding applications. For this profile, we developed three units: "Tailored Routes creator", "Multiplatform Apps Generator" and "Smartphone App". The first unit allows us to generate accessible routes using the collected information in the "Storage Unit". The second unit enables the management and generating of accessible and universal Wayfinding applications, which will be compatible with accessibility tools in Android and iPhone Smartphones. The third unit is the generated application.

2.2.2. Accessible data management unit

This Unit is an accessible web interface. It is used to access the GAWA stored information in the "Information Retrieval and Storage" unit 2.2.3. Functionality is next, when users access the GAWA from their browsers. They need to be logged in using credentials (this information will be provided by our group). They then choose their preferences on the website, type of disability (audio, visual, physical or cognitive), context of use and location. The unit provides information according to these choices using data filtering. This filtering accesses the database of the GAWA system using the previous unit.

Another key feature of the filtering process is the mode to obtain accessible tailored routes. When the user wants to access tailored routes, the unit accesses the Tailored Routes Creator (see Section 2.2.4) and the "Information Retrieval and storage Unit". The system has been developed to include accessible points, landmarks, information on barriers and major obstacles in the user's route for people with a disability.

The web interface of this unit has been developed according to the following criteria in order to be used in an accessible way:

- Testing the GAWA web page design with web accessibility tools.
- Compliance with current web standards for HTML 4.01 and Cascading Style Sheets (CSS), while maintaining accessibility for older browsers.
- Validating of pages with several tools, including the W3C's HTML Validation Service.
- Testing with Windows and numerous browsers (Safari, IE 7 & 8, Mozilla Firefox 3).
- Use of various accessibility checklists and guidelines, including those at www.w3.org/TR/WAI-WEBCONTENT.
- Use of headings, lists and web site structures in a consistent manner, including CSS to control the Web site's style and, in some cases, to control layout.
- A "Skip Navigation Link" option is available at the top of every screen. This allows users with mobility impairment and those who use screen-reader software to go directly to the main content and different menus of the application without having to deal with repetitive navigation links.
- Avoiding excess images, image maps and use of animated material.

Using adapted text according to the user pReferences

- Use of headings and control layout.
- Avoiding the use of frames.

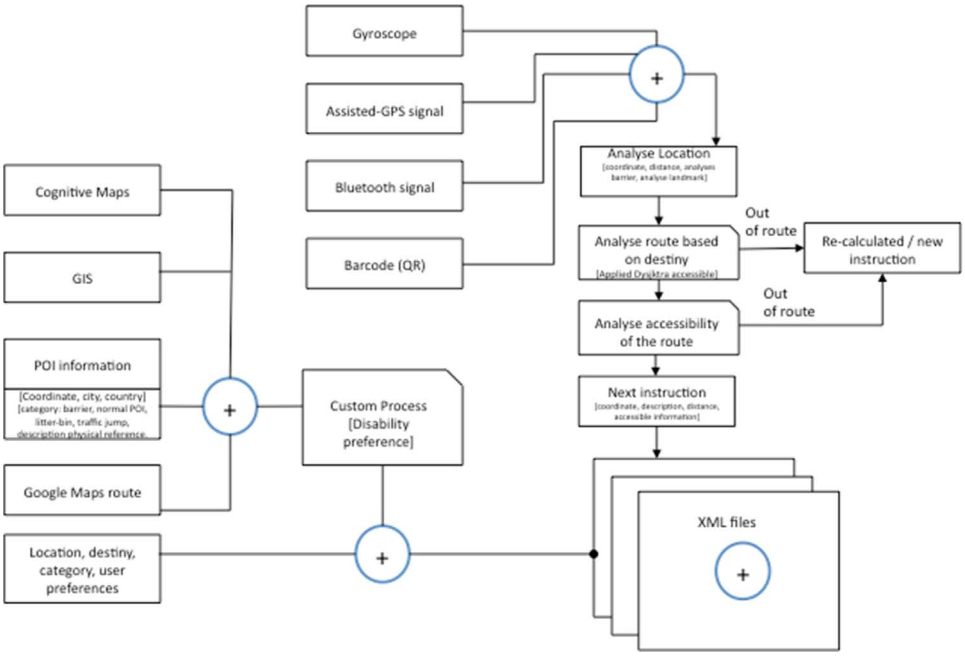

Fig. 3. Generation process.

2.2.3. Information retrieval and storage unit

This unit is the key to storage data collects, routes and applicable parameters for Wayfinding Services with a universal design and use. The unit has three main tasks.

The first is crawling to extract the data from the web on city places with accessible information. At the results section, we list the websites for validation. The crawler has two functions. Firstly, it obtains categories and definitions from the websites on POIs (description, type of POI, landmark, physical accessibility references, dimensions, public area, private area, adapted for people with a physical disability, braille description, multimedia, identification, location information, coordinates, city and country). In our previous work, we had 8 types of categories for crawler extraction: museums, churches, hotels, public transport, buildings, etc., however, in this work we have developed a function to create dynamic types in the crawling process. This unit generates new tables according to user demands or collected data (for instance: parks, universities, shopping centers, houses, city councils, etc.).

Secondly, the crawler stores and manages the collected data. This data contains accessibility information on POIs related to different places that are relevant to users. The information consists of accessible text, multimedia data, maps, routes, physical references, physical obstacles, colors of places and other relevant data. The important feature of this storage is that the crawler obtains more descriptions of the POIs than normal. This extra information is very important in order to offer accessibility information to people with a disability when they need to go to an unknown place in a city or building. For instance, dimensions of indoor (information on the building, etc.), outdoor parameters (sidewalks, litterbins, etc.), location of doors, location of stairs, location of emergency exits, location of elevators, information on adapted toilets, information on adapted rooms and contact. These parameters were chosen according to the analysis and design of the different research projects to build the GAWA systems.

The second is the management of accessible maps for POIs and tailored routes. This is useful for the navigation process. For such management, we used Cognitive maps (Salmeron, 2012). In familiar environments, humans orient themselves and navigate through space with the help of "cognitive maps"—mental representations of the surroundings, which form a model of the world according to the way it is perceived by a specific individual. These mental maps are formed while walking repeatedly through an environment and memorizing more and more details of the surroundings.

These Cognitive maps are used by the AMWA App to guide users in outdoor and indoor environments. The mechanism to store information on POIs and route maps comes next. We have a Google maps database for outdoor and a GIS database for indoor locations. In a booth database, we have included information obtained from the POIs, such as buildings (outdoor connections and indoor connections), floors of buildings (which includes building locations), walkways, litter-bins, pedestrian crosswalks, parking, location of trees, fire hydrants, traffic lights and bike racks etc., and part two consists of the layers representing the centerline of walkways and a layout of the inside of buildings. We also included in the database information on:

- Barriers or obstacles at a particular place: these elements in a multimodal Wayfinding situation are frequent. Barriers could be obstacles on the sidewalk, no elevator access or stairs, no access to a ramp, etc. For users with a physical disability, for example those that use a wheelchair, it is important for the Wayfinding system to allow an accessible and alternative route between different destinations.
- Landmarks: Landmarks are significant elements in the communication of route directions and part of mental representations of space. Local landmarks are either used at decision points, where a reorientation is needed, or serve as route marks, to confirm that one is going the right way (Westerbeek and Maes, 2013). For people with a disability, especially blind people, it is very important to accurately locate obstacles, bins, traffic jumps, streets, walkways, litter-bins, pedestrian crosswalks, parking, building plans, location of trees, fire hydrants, traffic lights and bike racks, etc.
- Indoor layer: The furniture and walls are pre-mapped in the database for indoor environments.

2.2.4. Tailored routes creator

This Unit is designed to generate tailored routes for outdoor and indoor environments with additional information for people with a disability. The process is as follows: the user accesses the unit using the Accessible Data Management Unit. The system provides the user with a menu to choose the POIs to make routes. These POIs are obtained from the Information Retrieval and Storage Unit. The user can choose two or multiple POIs for the route. The user then chooses tailored routes using the POIs.

In this step, the system can propose routes by default, which are obtained from Google maps or Open Street Maps. The user can overdraw these default routes or generate new routes. In both cases, the system will give users recommendations to include in the routes, such as landmarks and obstacles (extracted from the Information Retrieval and Storage Unit). Users can also include additional information (notifications) for a specific Wayfinding service. For instance, this information could be tourist information for tourist services, sensorial information even physical exercise POIs for cardio-health services (Ali and Khusro, 2016). Once the process is completed, the tailored routes and custom information is saved in the Information and Retrieval Storage Unit.

An important parameter to take into account in this Unit is the route qualities for pedestrians: to provide efficient navigational information, a network of paths used by pedestrians has to be defined. This is a special challenge, as people often consider different “optimum” routes to reach the same destination. Routes that are short can also be unattractive, if there are alternative routes that are less tiring or adapted for people with a disability.

Finally, the tailored routes need to be interpreted by the AMWA App to give personalized instructions to the end user. Therefore, when the Multiplatform Accessible Apps Generator makes the request, the Unit will generate two kinds of XML data files. The first has information on the tailored routes (accessible information, notifications for users, landmarks and obstacles). And the second and third consist of the layers representing the location points of the POIs (one for indoor and another for outdoor locations).

2.2.5. Multiplatform accessible apps generator

This unit focuses on the generation of the Assisted Multimodal Wayfinding Application (AMWA, which is described in the next section. In this process, personalization is considered in the planning process, according the user context (outdoor or indoor environment) and disability pReferences

When users want to generate an application, they only need to access this Unit using the Accessible Data Management Unit. The user chooses the city, buildings and type of Wayfinding Services (Tourist, Cardio-Health, Emergency Indoors, etc.). The system shows the POIs chosen by the user. The system then shows the option to start the generation.

At this time, the system makes calls to different internal scripts. The shows the different scripts and actions that generate the application. The compilation script to generate the application was described at our previous work. There are now new scripts that make requests to the Information Retrieval and Storage Unit and Tailored Routes Creator. These requests have been designed to generate files (interface, content and cognitive maps) for the AMWA App according to the following functionality criteria: the accessibility interface of the phone screen windows, the information on POIs based on the end user's preferences, the tailored routes in outdoor and indoor environments, the information on landmarks or obstacles, information of interest on proximity points along the route.

In addition, the unit can store the generated applications in the Information Retrieval and Storage Unit for the same application to be shared by different users.

2.2.6. Assisted multimodal Wayfinding application

The following is a description of the different implemented functionalities for the Assisted Multimodal Wayfinding Application (AMWA). The final generated Wayfinding applications can be installed in the user's Smartphone or Wearable devices. This application can guide users in indoor and outdoor environments according to their preferences (people with and without disabilities, languages, location, etc.). The application combines text, maps, auditory, augmented reality and tactile feedback to help users reach their destinations.

The first function allows the App to be used in a universal, accessible and functional way. Users with a sensorial, cognitive or physical disability are able to access the same application as people without a disability. Therefore, the application only changes the interfaces (colors, buttons and dimensions) and content (text, cognitive maps, multimedia, audio or subtitles) according to the end user.

The second function configures guidance modes according to the user preferences. To do so, the user receives assistance information in different ways using multimedia, voice, audio, image, text, maps, vibration, tactile feedback, etc. We call this the multimodal interface. The tactile compass provides continuous directional information through vibration and audio interfaces. The level of vibration depends on the proximity to the destination, landmark or obstacle. This is important for universal design oriented towards users with and without a disability.

The third function enables the application to integrate the elements that are not visible to users − such as street signs, pedestrian crossings, litter bins, etc. Providing this missing information is useful for users with a visual impairment. This information is obtained from the generated files in the Multiplatform Accessible Apps Generator unit.

The fourth function enables users to view information related to a particular place (text, multimedia, audio, etc.), write comments on it, be guided point to point with adapted information and share multimedia resources and reviews with other users. This multimodal information must be interoperable, exchangeable, accessible by all users everywhere and self-descriptive.

The fifth function is related to the information in cognitive maps. The layers are displayed on the phone screen and superimposed on the buildings that contain them in order to seamlessly guide users as they move indoors and outdoors. All the furniture and walls are pre-mapped in the database. Non-stationary obstacles can be located in real time by attaching beacons to them, although this is part of our future work. For this current system, we assume the furniture to be stationary.

The sixth function enables guidance to be accessible step by step. A routing table was created to define navigational instructions from each origin in the station to each possible destination. The obstacles, landmarks and Wayfinding orders (location elements) are represented by symbols in order to provide the necessary information for the audio guiding system. For this requirement, it is important to guide users at all times and locate elements, according to their position at the time, the goal to be reached and recalculation in case of error.

The seventh function allows the AMWA App continuous access to multimodal data (the second function), such as information on interest points in different environments and tailored routes. The applications must work properly in online and offline modes. In many places, there is insufficient coverage and applications based only on continuous data access will not work. For instance, the different floors in a building may have coverage and data problems to access online content. To sum up, tit does not matter whether a person is traveling by underground, in a village or a city.

The eighth function enables the application to continuously read instruction on the route. It allows users to access data, interpret instructions and directions according their preferences, and calculate the location-distance to the destination. We implemented Dijkstra algorithms, including new parameters: user disability, normal o critical situations and location elements. We use the same algorithm described in (Rodriguez-Sanchez et al., 2014Rodriguez-Sanchez, Moreno-Alvarez, Martin, Borromeo, & Hernandez-Tamames, 2014) for the location process. For indoor processing, we changed the outdoor signals to indoor signals.

When the user opens the application, he/she can choose the city or place (building) where guidance is required. The App can automatically locate the user and offer to begin guidance. Once the application is opened, it will provide the user with different choices (multimodal information, where am I?, access to cognitive maps for outdoor and indoor guidance, outdoor guidance and augmented reality).

For outdoor guidance, the App uses GPS, aGPS, 3G, Wi-Fi the phone camera and sensors installed in the phone. For indoor guidance, the

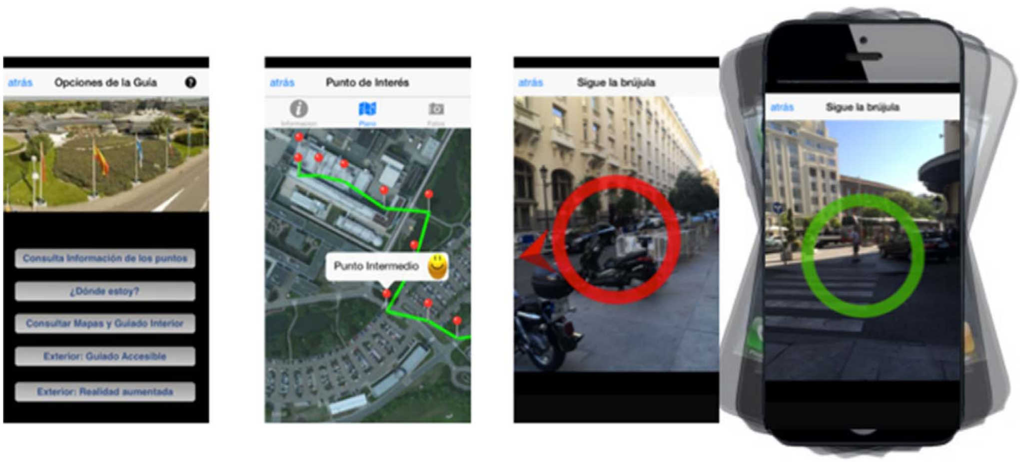

Fig. 4. Screenshot of the AMWA App in an outdoor environment with tactile, vibration, voice and multimedia feedback.

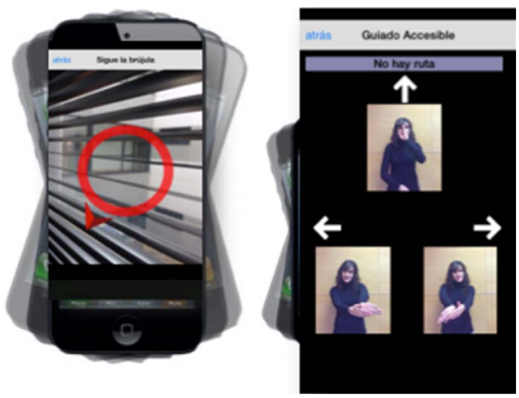

Fig. 5. Screenshot of an AMWA App in an indoor environment with tactile, vibration, and sign-language feedback.

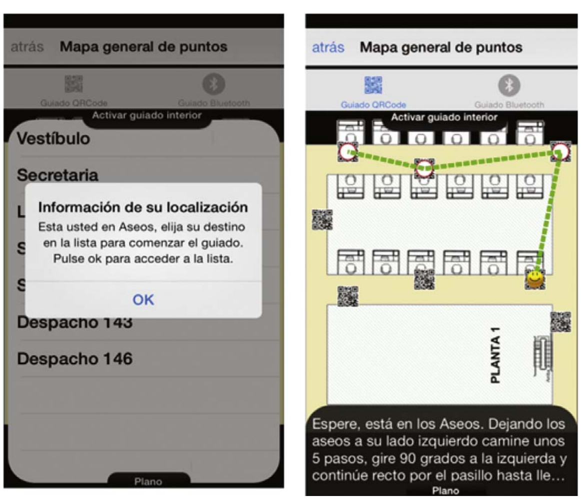

Fig. 6. Screenshot of an AMWA App for an indoor environment with tactile, vibration, voice and multimedia feedback.

navigation receives information from Bluetooth beacons. In addition, the system allows guidance using QRcodes. For this guidance, the user only needs to activate the phone camera close to a QR-code. The App analyzes the QRcode, locates the user and starts the guidance. In Figs. 4–6 , we show different examples with screenshots. The first is the main screen of the App, with an example of outdoor navigation using maps and augmented reality. The second is an example using sign-language feedback and the last an example of indoor location and guidance. Besides, during the guidance, if the end user finds an element, obstacle or something that is not included in the application information, he/she can make a request to the Database and Storage Unit from the app.

We have a previous application described in (Rodriguez-Sanchez et al., 2014). In the previous version, the App was designed only for outdoor use. We changed it for indoor use and to include modules to be generated automatically by the GAWA system.

3. Evaluation

In this section, we evaluate the GAWA system as a reference of Accessible Tool to manage and generate multimodal Wayfinding applications and their contents. For this process, we evaluated the following items: the content accessibility guidelines of the GAWA system, the deployment of this proposal in three scenarios, the experimental evaluations with users for the scenarios describing the evaluation procedure and, finally, a discussion of the evaluation and comparison with other solutions is provided.

3.1. Accessibility guidelines validation

We validated the accessibility of our proposal using the free accessibility validators described in Table 1. These tools can evaluate the Web Content Accessibility of the GAWA system to make content accessible to people with a disability. To do so, we followed the Web Content Accessibility Guidelines (WCAG2.0) to obtain the maximum level (AAA). Table 2 shows the results of applying these accessibility validators to GAWA systems.

In this evaluation, the only advice was that our interfaces could be changed according to different colors. Therefore, we can conclude that we obtained excellent results, as we passed the maximum level (AAA). We have used these validators with other websites and solutions in Spain relating to social services (see Table 3). Although the entities obtained the WCAG 1.0 AA level, we found different errors related to the type of letter, customizing of interfaces, links and buttons, etc. Our accessibility of the GAWA system is therefore better than these relevant entities.

Table 1
Accessibility Validators – tools online and offline.

Name of Tool	Accessibility Validation	Online/Offline
TotalValidator	AAA	Offline
TAW	WCAG1, WCAG2, A, AA, AAA	Online
INTAV – Inteco	WCAG 1.0, UNE-139803	Online
Examinator	WCAG2	Online
Web Accessibility Checker (Achecker)	WCAG2	Online

Table 2
Results of the accessibility test using the accessibility validators described in Table 1.

Level of Accessibility	WCAG1			WCAG2		
TotalValidator	A	AA	AAA	A	AA	AAA
Taw	Yes	Yes	Yes	Yes	Yes	Yes
Intav	Yes	Yes	Yes	Yes	Yes	Yes
Examinator	Yes	Yes	Yes	Yes	Yes	Yes
Achecker	Yes	Yes	Yes	Yes	Yes	Yes

Table 3
Accessibility Validation of relevant entities for people with a disability in Spain and the GAWA system.

Institution or System	Accessibility Validation	Errors
ONCE Foundation (ONCE is the National Organization of the Blind in Spain)	WCAG 1.0 A	3
Predif www.predif.org	WCAG 1.0 AA	10
Ministry of Health, Social Services and Equality	WCAG 1.0 AA	4
Madrid website (capital of Spain)	WCAG 1.0 A	10
European Parliament	None.	5
GAWA	WCAG 2 AAA	1 (the color of the web)

3.2. Development of the gawa system in three case studies

We deployed the GAWA system in three scenarios for this evaluation. The three scenarios in which the GAWA system was developed were: an indoor environment, an outdoor environment and both environments. These developments were used to evaluate the results, advantages and problems of our proposal. The following subsections describe: the platform constraints, the preferences and profiles of participants in the evaluation, the description of three case studies and finally the evaluation procedure.

3.2.1. Platforms constraints

We evaluated the installation and operation of the GAWA system server in different platforms (Windows and Linux). Table 4 shows the two platforms (A and B) with the different characteristics. Table 5 shows the result of the crawling of DBPedia, Predif and Wikipedia to extract POIs automatically. In Table 6, we measure the workload for crawling using the Platforms A and B. For both platforms the system extracted the same number of POIs (Table 5). For the final development in the three scenarios, we realized that the time was better for the type A platform.

For the validation of functionality and accessibility of the generated smartphone applications (AMWA Apps), we used different smartphones to validate the application: Samsung Galaxy (S, SII, SIII, SIV, SV), BQ 4G, HTC Desire and Motorola Dephi using the Android platform. These Android devices have a 4-inch capacitive touch screen with multi-touch support. Furthermore, we also used iPhones 3G, 4G, 4GS and 5S. The proposal was to check that the same application ran in the same way in the different platforms. As stated above, our proposal was successful.

Table 4
Type of Platform for GAWA system.

	Computer Type A	Computer Type B
Type of Server	Local	Remote
Processor	Intel Core i5 2.65 Ghz	Intel Cores i5 1.6Ghz
Memory	4 GB	3402 MB
Internet Connection	40 Mbps	100 Mbps
SSOO	Windows 7	Ubuntu 10.04.4
Java	Java 1.7.0_21	Java.1.6.0_21 Java 1.7.0_10
Tomcat	Apache Tomcat 7.0.39	Apache Tomcat 7.0.6
Mysql	Mysql 5.0.51b	MySql 5.5.29

Table 5
Evaluation of crawling for POIs.

Type	Correct	Duplicated
Museum	342	17
Stadium	201	21
Hospital	60	8
University	144	49
Station	228	0
Commercial Center	16	0
Cultural Places	7	4
Hotel	6	0
Bridges	56	4
Total	1060	99
General Information	1397	181
Total	1397	181

Table 6
The Workload of crawling in Platform A and B.

Platform	Correct	Duplicated
A	2′30″	13″
B	5′11″	1′35″

3.2.2. Participants in the trials

The system was evaluated in the different scenarios described in the sections below over three years. We recruited people from the Spanish organization for the blind (ONCE), the Vodafone Foundation and university students.

The participating group was comprised of 11 males and 9 females, aged from 20 to 75 (25% within the age range of 21–30, 50% from 31 to 50 and 25% from 51 to 77). They were divided into three categories: users without a disability (8), blind users (3) or limited vision users (4), deaf users (3) and users with a wheelchair (2).

3.2.3. Description of case studies

In this section, we describe the 3 case studies for our proposal in real environments. One for indoor, another for outdoor environments and one for both. Firstly, we present a table with different parameters of development for each case study. In addition, for each environment, we show a map and some relevant pictures of validation.

Table 7 shows the different parameters chosen to show the differences: the type of guidance that could be indoor, outdoor or both; the QR-code location, this parameter being oriented to validate the use of location with the AMWA application using QR-codes; QR-code navigation, this parameter being oriented to validate the use of location with the AMWA application using QR-codes; the Bluetooth location, this parameter being oriented to validate the use of location with the AMWA application using Bluetooth technology (Bluetooth beacons); Bluetooth navigation, this parameter being oriented to validate the use of location using Bluetooth, if it is possible for the application to work in panic mode to be guided in emergency situations; GPS location, this parameter being oriented to validate the use of location with the AMWA application using GPS and our algorithms for outdoor locations; GPS navigation, this parameter being oriented to validate the use of location using GPS and our algorithms for outdoor locations; the next parameter is the number of POIs; the number of landmarks is related to physical references, obstacles, etc.; the months are related to the duration of validation in months for the scenario; the next parameter is the numbers of buildings; for each building the validation could be on one or two floors; finally, the last parameter is the Smartphone platform which could be Android, iOS or both.

As we can see, in the first case we developed and validated our

Table 7
Description of characteristics for the validation of the 3 scenarios.

Characteristics	Case 1	Case 2	Case 3
Type of Guidance	Indoor	Outdoor	Indoor and Outdoor
Qr-code location	Yes	No	Outdoor: yes, Indoor: yes
Qr-code guidance	Yes	No	Outdoor: yes, Indoor: yes
Bluetooth location	No	No	Only indoor
Bluetooth guidance	No	No	Only indoor
Bluetooth guidance for emergency situations	No	No	Only indoor
GPS location	No	Yes	Only outdoor
GPS guidance	No	Yes	Only outdoor
Number of POIs	10	8	Outdoor 11, Indoor: 38
Registered Landmarks	40	56	Outdoor 144, Indoor: 10
Validation – Number of Months	10	3	24
Number of buildings	1	8 (each POI)	Outdoor 11, Indoor: 1
Numbers of floors	2	–	Outdoor: 0, Indoor: 1
Dimension of a floor	$175m^2$	–	$125m^2$
Smartphone Platforms	Android and iOS	Android and iOS	Android and iOS

GAWA platform in an indoor scenario: one building with two floors (each floor measuring $175m^2$). Fig. 7 shows the maps of the building (example of a building where there are usually many people every morning: a council building). On the right side, there is a picture of a generated application for this scenario. The objective was the validation of the location and navigation using the AMWA application for indoor environments. We generated the information for the application using the online management of the GAWA. The GAWA system allows us to choose different names for the generated applications. We called this application "StepByStep" (available on Android Store: "PasoAPaso" in Spanish).

In the second case, we developed GAWA for an outdoor environment in the city of Madrid, with 8 POIs related to tourism. Fig. 8 shows a 15 km map. An example of a route (15 km) is market between the 8 POIs. This scenario was designed for a tourism and cultural scenario called the "Guadalupe" route.

Finally, in the third case, GAWA was deployed in outdoor and indoor environments. The context was an educational environment in which people usually go to the university, library and laboratories. The table above shows the different characteristics of both environments.

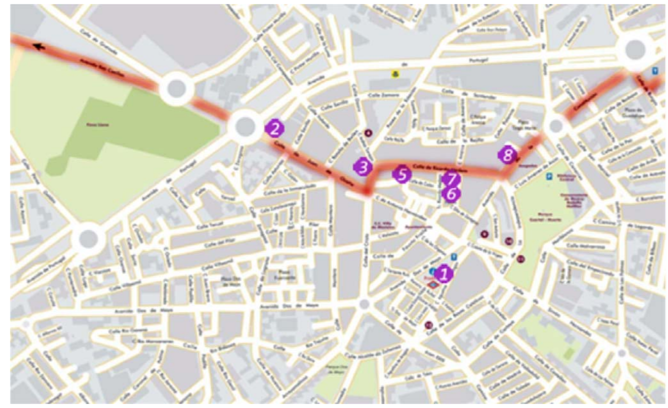

Fig. 8. Map for the outdoor scenario used in case 2 (15 km with 56 landmarks and 14 obstacles).

We included different examples of routes between POIs in the maps. The map and users using the AMWA application appear in Figs. 9 and 10. The application, information on POIs, routes and landmarks were generated using the online management of GAWA. Moreover, in this case we validated the use of guidance in emergency situations. We collaborated with the University and Security Program to define the information for the users in emergency situations. The emergency information and routes from buildings was stored in the GAWA Accessible Management Storage Unit (see **Error! Reference source not found.**). We simulated critical situations with a demo alarm. Users were located and guided in the same way as in a normal situation, but the messages and information was adapted to emergency situations.

We therefore deployed the GAWA system in 3 cases. Each case had different context proposals, which are useful in the daily lives of people with and without a disability.

3.3. Trials – experimental evaluation of the GAWA system and AMWA app

3.3.1. Evaluation trials

With the aim of evaluating the Wayfinding application developed, we performed three trials in the three case studies mentioned above, for different groups of people: people without a disability, visually impaired people, deaf people and people with a motor disability. In addition, for each scenario (indoor, outdoor and both), we carried out three trials: one for testing the application using Android devices, another for testing the application using iOS devices and the third trial for testing the GAWA-system web.

The first and second trials were intended to validate the AMWA

Fig. 7. Plan for indoor scenarios in case 1.

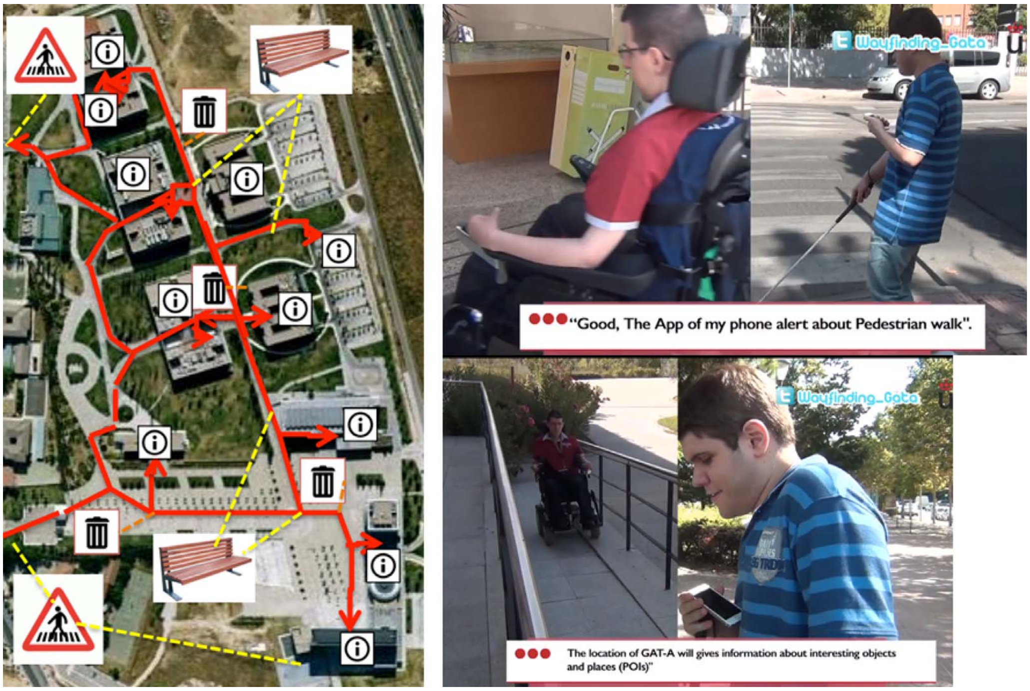

Fig. 9. Outdoor Map in case 3 with 11 POIs (outdoor) and landmarks for litter bins, pedestrian crosswalks and benches.

Fig. 10. Indoor map of case 3 for a building (University).

App. For both trials, the participants were asked to navigate along three pre-calculated routes in the three cases: the first, three indoor routes; the second, two routes only outdoor; and in the third, we evaluated two outdoor routes, in which one is for an outdoor starting point to an indoor destination and the other from an indoor starting point to an outdoor destination.

In the last trial, to generate applications using the GAWA system, one AMWA App was generated for Android and one for iOS devices using laptops and tablets with the Chrome and Internet Explorer browsers. For this trial, they used the Apps development profile (see Fig. 2).

Given that this evaluation includes people with different preferences, the objective was to validate the usability and feasibility of the web to manage information with accessibility criteria and the Wayfinding application generation process in a universal way.

3.3.2. *Evaluation of trials*

We evaluated the trials using direct observation and questionnaires for the generation process and the AMWA App.

3.3.2.1. GAWA system on-line web. For the generation process trial, the participants used familiar browsers to access the App Development profile (see Fig. 2); the users could be familiar with interfaces such as Google Chrome, Safari or Internet Explorer. We validated the usability of the web by people with a disability with the screen reading software and accessibility interfaces for. The users were provided with an accessible manual on how to use the web from their homes.

The process evaluation consisted in the generation of 3 applications. For each application, the users had to choose 10 POIs from six cities in two languages. Then, they had to make up to 5 routes using the POIs. The system automatically added obstacles, barriers and physical references, which could be along the routes. For this task, the system used the GPS coordinates of the selected POIs and routes. Once the participants had generated information and Wayfinding applications, we tested and evaluated the applications using the APIs of Google maps. We checked that the application had the POIs and routes.

The next process was to generate one application in each case described above to validate the applications *in situ*. The users therefore installed the applications in their smartphones to validate them in the trials described above. During the trial, if the users detected new obstacles or physical references that were not included in the application, they could upload information from the application or from this online web.

The online service management of GAWA to generate applications and updates could be accessed anywhere and at anytime. The GAWA was designed and developed for different contexts in SmartCities (daily life, university, tourism and emergency situations). Moreover, we developed different functions as a tool to help manage and collect information in 26 different languages in the application. This could be very useful for tourism contexts. Even if the geographical mobility only has a regional scope in any EU country, with this technology we will be improving people's autonomy, tourism opportunities and, more importantly, their "daily lives" by reducing the physical barriers. We are sure that we can bring global solutions to the expected 75 million people with a visual disability in 2020 in the world, according to the OMS.

The evaluation of the online web was performed with the following questions, which the users had to answer with a value in the range of 0–5:

Q1: How accessible is this system from your laptop device?

Q2: How easy was it to choose the cities and POIs following the web instructions?

Q3: Are you satisfied with the POIs and language suggested by the

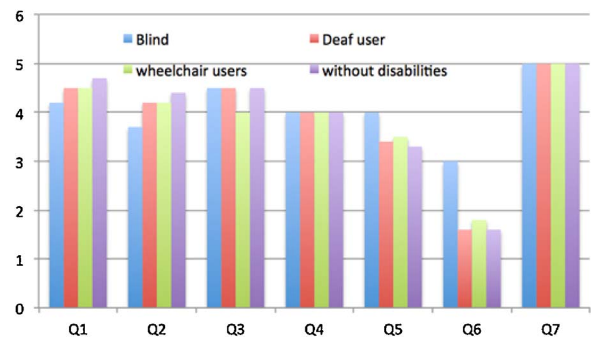

Fig. 11. Usability questionnaire for the GAWA system online web. Average replies to the questions. In Q5 and Q6, answer 5 is 3 min, answer 4 is 5 min, answer 3 is 10 min, answer 2 is 12 min, answer 1 is 15 min and answer 0 is other minutes. Fig. 12 shows the average replies to the questionnaire.

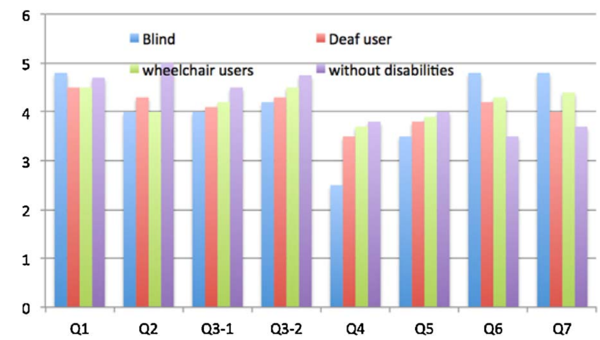

Fig. 12. Usability questionnaire for the mobile application. Average replies to the questions. In Q5 and Q6, answer 5 is 3 min, answer 4 is 5 min, answer 3 is 10 min, answer 2 is 12 min, answer 1 is 15 min and answer 0 is other minutes. Fig. 12 shows the average replies to the questionnaire.

web?

Q4: Did you find the route generation and automatic management of the physical obstacles or barriers useful?

Q5: How long did it take you to generate the last application 3, 5, 10, 12, 15 or more minutes?

Q6: How long did it take you to generate the last application 3, 5, 10, 12 or15 min?

Q7: Once you generated the application, how easy was it to share with other friends or users?

Q1 is a positive accessible validation using different browsers and devices with the screen reading software. Comparing the user satisfaction expressed in Q2-Q4, we observed that the evaluation was very positive, as users were able to use the system without problems. The accessibility and universality was validated with this evaluation. With regard to Q5-Q6, we demonstrated that most users do not need to waste time using the online management. Therefore, we can export this solution to the smart mobility and smart people management for the Wayfinding services. Finally, the last question is an example of sharing cloud services (Fig. 11).

3.3.2.2. AMWA App. We followed two steps to evaluate this kind of application. The first step relates to the interfaces and the accessibility of the AMWA App. One of the key points for these trials was to obtain feedback on which is the best option when the application provides information to users.

At the beginning of the trials for the Wayfinding application, a short introduction to smartphones and the case study was provided to the participants. The participants were seated at a desk in front of a smartphone (Android or iOS) and introduced to the devices, the screen reading software (Voiceover, Talkback and Blind-Launcher) and the Wayfinding application. A visually impaired user can navigate through the basic functionalities of the smartphone and open the navigation application autonomously, thanks to the screen reading software. The Wayfinding application guides users through an adapted interface and they receive instructions on the direction to walk in order to arrive at a destination using tactile, audio and text functionalities. A map can also be displayed with dynamic information on the route.

Once the users with a visual impairment were familiar with the devices and the screen reading software, they started to test the Wayfinding application outside. At the same time, the remaining users started to follow the routes for the evaluation.

While participants were using the Wayfinding application, observers were taking notes on the success rate of each task and the time required to complete the activity. Specifically, the elements observed and recorded are summarized below:

- Selecting Wayfinding option from the building entrance to the destination.
- Measure of route points followed to a destination.
- Time spent from the starting point (building) to the subway.
- Time spent from the subway to the starting point.

We evaluated usability and feasibility based on the following questions which the users had to answer with a value in the range of 0–5:

Q1: How accessible is this application from your Smartphone?

Q2: How easy was it for you to follow the outdoor routes?

Q3-1: How easy was it for you to follow the indoor routes?

Q3-2: How easy was it for you to follow the indoor routes in emergency situations?

Q4: How long did it take you to follow the outdoor routes, 3, 5, 10, 12, 15 or more minutes?

Q5: How long did it take you to follow the indoor routes 3, 5, 10, 12, 15 min?

Q6: Did you find the application feedback information useful?

Q7: Did you find the notifications and accuracy of the application on physical obstacles or barriers useful ?

Q1 is a positive accessible validation using the different Smartphones described above. The second step relates to the location and navigation process. With regard to navigation using the App, the route points from the starting point to destination were reached in most cases in the three scenarios (Q2-Q5). The users choose multimedia, audio, touch screen and tactile feedback to be located and guided (only deaf users use multimedia without audio). The application also provides alarms to the user and redirects to the correct route. This lack of physical reference was the cause of 29% of the route points that were not followed accordingly. However, limited vision users do not usually need many physical references and they had no problems reaching all the route points. We have improved this measure using physical reference alerts in the Wayfinding application using the second mode based on phone vibration. The user receives auditory and vibration information on physical references in the route between different points without the influence of environmental noise. Therefore, this mode is more efficient.

Similar results were obtained for the simulation of emergency situations. Users were detected and guided in the same way. However, they were very satisfied because they defined a very useful function of our proposal. In this last case, we stored the information in the online management system under supervision of the Security Program of our university. The application also included different kinds of messages adapted to the different user profiles (see example in https://youtu.be/BYijNMB7xSI). We are working to integrate this last function into new projects related to emergency situations and firefighting utilities.

For instance, blind people and limited vision users spent 14 min and 11 min respectively from the starting point to the subway station. Deaf users and people with a motor disability spent the same time as people without a disability: 9 min and 22 s. In the return route, the average time decreased to 6 min for all users, except for blind users (only

3 min). In this last trial, blind users had no problems being guided thanks to the accuracy of the application (1–3 m for indoor and outdoor environments).

Another important result was that the information and feedback in real time was very useful to the users. The helpfulness of the vibration feedback is based on distance and directional information was validated in the results. The users feel very confortable using the application with this function (Q6). Moreover, the accuracy of outdoor and indoor location (1-3 m) allowed alerting users about physical references such as obstacles, things like street signs, doors, litterbins, a perimeter fence or pedestrian crossing. These alerts were messages to improve the mobility and interaction with the environment. According to the answers to Q7, the users evaluated these results in a positive way. In the questionnaires, most people found the AMWA App useful for orientation, irrespective of disabilities and preferences. Although we faced certain technical problems, the participants liked the idea of being continuously guided in a multimodal way between indoor and outdoor POIs.

3.4. Discussion

The European Economic and Social Committee (CESE) welcomes the European Disability Strategy 2010–2020 (EED) which considers as an active policy instrument to implement the Convention on the Rights of Persons with Disabilities (http://www.un.org/disabilities/convention/conventionfull.shtml). One of these objectives is the improvement of Participation in cultural life, recreation, leisure and sport. Therefore, a key issue is to promote mechanisms that enable access to venues of cultural performances or services, such as theatres, museums, cinemas, libraries and tourism services and, as far as possible, to enjoy access to monuments and sites of national cultural importance.

An important aspect to be considered is that the AMWA and the GAWA System is accessible by a huge number of people, irrespective of the user's needs or abilities, thanks to the use of different sensory channels (visual, auditory and tactile) that provide information. Moreover, the GAWA was validated for different contexts and case studies to demonstrate the universality of the solution. Therefore, we working to offer mechanisms for universal and accessibility design. Furthermore, we consider it very important to have access to the information and be able to navigate anywhere and anytime, in fact, this solution work in online and offline mode to operate properly.

The results of the previous section validate the accessibility and functionality of this proposal. Furthermore, the modularity and online management of the platform can solve a number of economic barriers and provide a tool through mobile technology. Accordingly, there are different entities into which the platform can be integrated: the European Network of Accessible Tourism; Companies like an Accessible Europe, (http://www.accessibleurope.com/), the Vodafone Foundation; Travel agencies for accessible journeys such as www.disabilitytravel.com, Sherpandipity. These entities can manage Wayfinding services, update information, routes, maps anywhere and anytime. Another way to enable the maintenance of the platform could be through advertising, through special offers or discounts that may be beneficial for end users. In addition, our aim is for this engagement to allow us to increase our R + D in collaboration with safety entities, as we are already working to provide other solutions for people with cognitive and motor disabilities.

In contrast to (Rehrl, Bruntsch, & Mentz., 2007), the key issue relating to positioning, descriptions of buildings, transition between indoor and outdoor routes, generation of the route descriptions in different environments and accessibility criteria have been resolved. In Table 8 below we show the differences between the GAWA systems and other solutions for Wayfinding services. We validated parameters such as crawling, language, WCAG, Accessibility, indoor navigation, outdoor navigation, tailored routes, management of information and availability for other scenarios such as emergency situations. As shown, the

Table 8
A comparative table of different solutions for Wayfinding services in Smartcities.

Platform	Crawling	Language	WCAG	Accessible App	Indoor & Outdoor	Tailored Routes Outdoor	Tailored Routes Indoor	Management of Information	Available for Emergency Situations
GAWA	DBPedia, Wikipedia, Predif.	26 different	WCAG 2.0 AAA	Yes	Yes	Yes	Yes	Yes	Yes
Compass	No	1	No	No	Outdoor	?	No	Yes	No
T-Guide	No	1	?	Yes	Outdoor	No	No	Yes	No
Predif	No	1	WCAG 1.0	Yes	Outdoor	Yes	No	Yes but not the generation of Apps	No.
RADAR	No	1	?	No	Indoor	No	Medium	?	Yes.
Drishti	No	1	?	Yes, visually impaired users.	Yes, limited	No.	?	?	?
UCPNavi	No	1	No	No	Indoor	No	?	?	No.
Huang and Liu	No	1	No	Yes, only visually impaired users.	Indoor	No	Medium (Dijkstra)	?	No.
REAL	?	1	?	No? not sure	Yes	Different options of the routes.	?	?	No.
WSI-GO	No	1	No	Yes, only cognitive limitations users	Outdoor	Different options of the routes.	No.	No.	No.

proposed solution is the most complete offer for Smartcities.

4. Conclusion and future research

In this work, we introduce the GAWA system that provides a complete, universal and accessible solution to manage the basic functions of a smartphone and guide users using a Wayfinding application. Whereas related systems typically work in only one of the two environments, users of GAWA are able to generate Wayfinding applications with a universal design for indoor and outdoor environments through a web, without the need for programming skills, assisted by a system of automatic generation and updating of points of interest. The GAWA system can be applied to different contexts of application for Smartcities. For instance, it could be used for tourism, university, daily life or emergency situations.

In contrast to (Nasir et al., 2014; Rodriguez-Sanchez, Martinez-Romo, Borromeo, & Hernandez-Tamames, 2013) the generated applications are multiplatform and GAWA does not need developers to manage its functionality options in indoor or outdoor locations. GAWA also helps to integrate standard rules on equal opportunities for people with a disability in cities related to mobility, through a system designed to manage Wayfinding services for outdoor environments with an accessible and universal design. This proposal is scalable, sustainable and a powerful model for smartcities. The platform consists of a Wayfinding smartphone application for an online management service through a Web application.

The smartphone application can be used in outdoor and indoor environments. For outdoor guidance, our system interacts with the environment, combining different technologies (GPS, aGPS, 3G, Wi-Fi and phone cameras and sensors). In the case of indoor environments, mobile devices use technologies such as Bluetooth, NFC, bi-dimensional codes (QRcodes) and its sensors to obtain the location. The accuracy can be 1–3 m for both environments. We designed guidance for normal and emergency situations (when the user has to know the shortest route to exit quickly and in real time).

The online management service is a tool that allows, generates and manages Wayfinding applications. The tool supports tasks for indoor and outdoor positioning based on accessibility criteria included in the generated Wayfinding application without programming knowledge.

The GAWA system is the evolution of a previous work called GAT (Rodriguez-Sanchez et al., 2013). The new contributions of GAWA with respect to GAT are:

- Accessibility for people with a disability to the management of information and Wayfinding applications.
- Management of accessible information on Interest Points and Landmarks automatically.
- Tools to generate tailored routes with landmarks in outdoor and indoor environments.
- Routes in several cities or places in the same mobile application. Previously, each city or place had to be handled in a different application.
- Validation and certification of the information, routes and landmarks for people with a disability.
- The same application for location and guidance with high accuracy in outdoor and indoor scenarios. The guidance is automatically configured according to the user's preferences. For this purpose, the user receives assistance information on different ways using multimedia, voice, audio, image, text, maps, vibration, tactile feedback, etc. We call this multimodal interface. To obtain a universal design oriented towards users with and without a disability, this was an important issue to take into account.
- An online management service that allows generation of Wayfinding applications oriented towards people with a disability in emergency situations.
- Points of interest, landmarks and routes can be managed and updated anywhere and anytime using the online management service.
- New functionality to share and distribute new mobile applications and updates.

To sum up, this new proposal creates an unprecedented number of opportunities to build on innovative value for Smartcities in terms of mobility, people, governance and accessibility. The GAWA system facilitates the process of management and monitoring of Wayfinding services by people with and without a disability in outdoor and indoor environments.

4.1. Future research

We will work to integrate Galileo and GPS. This improvement could provide several advantages, as the free version should be available to everyone. We have become dependent on services provided by satellite navigation in our daily lives, as well as for tourism. In addition, Galileo will improve the overall availability and coverage of GNSS (Global Navigation Satellite System) signals. Therefore, we can solve another problem related to high-rise cities, where buildings can obstruct signals from satellites; Galileo-GPS has a higher number of satellites which should improve the availability of the signals in high rise cities to obtain accuracy to a few centimeters.

References

AEGIS, Sitio web: http://www.aegis-project.eu.

ASK-IT, Sitio web: http://www.ask-it.org.

Abascal, J., Boanil, B., Gardeazabal, L., Lafuente, A., & Salvador, Z. (2009). Managing intelligent services for people with a disability and elderly people. *Lecture Notes in Computer Science*, *561*, 623–630.

Ali, S., & Khusro, S. (2016). Mobile phone sensing: A new application paradigm. *Indian Journal of Science and Technology*, *9*(19).

Angin, P., & Bhargava, B. K. (2011). Real-time mobile-cloud computing for context-aware blind navigation. *International Journal of Next-Generation Computing*, *2*(2).

Bonner, M. (2010). *No-Look notes: Accessible eyes- free multitouch text-Entry. pervasive computers*. 409–426.

Borràs, J., Moreno, A., & Valls, A. (2014). Intelligent tourism recommender systems: A survey. *Expert Systems with Applications*, *41*(16), 7370–7389.

Brumitt, B., Meyers, B., Krumm, J., Kern, A., & Shafer, S. (2000). Easyliving: Technologies for intelligent environments. *The second international symposium on handheld and ubiquitous computing (HUC2000)* (pp. 12–29).

Caragliu, A., Del Bo, C., & Nijkamp, P. (2011). Smart cities in europe. *Journal of Urban Technology*, *18*(2), 65–82.

De Oliveira, K. M., Bacha, F., Mnasser, H., & Abed, M. (2013). Transportation ontology definition and application for the content personalization of user interfaces. *Expert Systems with Applications*, *40*(8), 3145–3159.

Downs, R. M., & Stea, D. (1977). Maps in minds: Reflections on cognitive mapping. *Harper & Row*.

ENAT, (European Network Accessibility Tourism) Sitio web: http://www.accessibletourism.org.

Ficco, M., Palmieri, F., & Castiglione, A. (2014). Hybrid indoor and outdoor location services for new generation mobile terminals. *Personal and Ubiquitous Computing*, *18*(2), 271–285.

Fickas, S., Lemoncello, R., & Sohlberg, M. M. (2010). Where am I: How travelers with a cognitive impairment ask for and use help. *1st international workshop on user modeling and adaptation for daily routines: Providing assistance to people with special and specific needs* (pp. 5–18).

Fink, J., Kobsa, A., & Nill, A. (1999). *Adaptable and adaptive information provision for all users, including disabled and elderly people, To appear in New Review of Hypermedia and Multimedia*.

García de Marina, A. G., Carro, R. M., & Haya, P. (2012). Where should I go?: Guiding users with cognitive limitations through mobile devices outdoors. *Proceedings of the 13th international conference on interacción persona-ordenador* (pp. 46–). .

Gartner, G., Frank, A. U., & Retscher, G. (2004). *Pedestrian navigation system in mixed indoor/outdoor environment-the navio project. na*.

Giffinger, R., Fertner, C., Kramar, H., Kalasek, R., Pichler-Milanovic, N., & Meijers, E. (2007). *Smart cities-Ranking of European medium-sized cities*. Vienna University of Technology.

Giudice, N. A., & Legge, G. E. (2008). *Blind navigation and the role of technology. Engineering handbook of smart technology for aging, disability, and independence*. 479–500.

Hersh, M., Ohene-Djan, J., & Naqvi, S. (2010). Investigating road safety issues and deaf people in the United Kingdom: An empirical study and recommendations for good practice. *Journal of Prevention & Intervention in the Community*, *38*(4), 290–305.

Jain, D. (2014). Pilot evaluation of a path-guided indoor navigation system for visually impaired in a public museum. *Proceedings of the 16th international ACM SIGACCESS*

conference on computers & accessibility (pp. 273–274).
Kane, S. K., Wobbrock, J. O., & Ladner, R. E. (2011). Usable gestures for blind people: Understanding preference and performance. *Proc. CHI '11* (pp. 413–422).
Klante, P., Krösche, J., & Boll, S. (2004). Accessights –a multimodal location-aware mobile tourist information system. *International conference on computers helping people with special Needs(ICCHP)*. *2004*, (pp. 187–294).
Kramers, A. (2014). Designing next generation multimodal traveler information systems to support sustainability-oriented decisions. *Environmental Modelling & Software*, *56*, 83–93.
Li, C. (2006). User preferences, information transactions and location-based services: A study of urban pedestrian wayfinding. *Computers, Environment and Urban Systems*, *30*(6), 726–740.
Microsoft Research, Mobile Indoor Localization Sitio web: http://research.microsoft.com/en-us/projects/indoorloc/.
Microsoft Research, RADAR Sitio web: http://research.microsoft.com/en-us/projects/radar/.
Mielke, M., Grunewald, A., & Bruck, R. (2013). An assistive technology for hearing-impaired persons: Analysis, requirements and architecture. *Engineering in medicine and biology society (EMBC), 2013 35th annual international conference of the IEEE* (pp. 4702–4705).
Millonig, A., & Schechtner, K. (2007). Developing landmark-based pedestrian-navigation systems. Intelligent transportation systems. *IEEE Transactions on*, *vol. 8*(1), 43–49.
Montello, D. R., & Sas, C. (2006). *Human factors of Wayfinding in navigation*.
Nasir, M., Lim, C. P., Nahavandi, S., & Creighton, D. (2014). Prediction of pedestrians outes within a built environment in normal conditions. *Expert Systems with Applications*, *41*(10), 4975–4988.
O'Hare, G. M. P., & O'Grady, M. J. (2003). Gulliver's genie a multi- agent system for ubiquitous and intelligent content delivery. *Computer Communications*, *26*(11), 1177–1187.
OASIS, Sitio web: http://www.oasis-project.eu.
Oliveira, J., Guerreiro, T., Nicolau, H., Jorge, J., & Gonçalves, D. (2011). Blind people and mobile touch-based text-entry: Acknowledging the need for different flavors. *Proc. ASSETS '11* (pp. 179–186).
Oulasvirta, A., Tamminen, S., Roto, V., & Kuorelahti, J. (2005). *Interaction in 4-second bursts: The fragmented nature of attentional resources in mobile hci*. *CHI '05: SIGCHI conference on Human factors in computing systems*, . ACM Press919–928.
Pielot, M., Poppinga, B., & Boll, S. (2005). PocketNavigator: Vibro-tactile waypoint navigation for everyday mobile devices. *Proc. of the 12th international conference on human computer interaction with mobile devices and services (MobileHCI 2010)* (pp. 423–426).
Plataforma Accesible-EU, AAA Sitio web: http://www.accessible-eu.org.
Poláček, O., Grill, T., & Tscheligi, M. (2012). Towards a navigation system for blind people: A wizard of oz study. *ACM SIGACCESS Accessibility and Computing*, *104*, 12–29.
Poslad, S., Laamanen, H., Malaka, R., Nick, A., Buckle, P., & Zipf, A. (2001). *CRUMPET: Creation of user-friendly mobile services personalised for tourism 3G*. London.
Predif, Sistema Gestor de Turismo Accesible Disponible en: http://www.predif.org.
Ran, L., Helal, S., & Moore, S. (2004). Drishti: An integrated indoor/outdoor blind navigation system and service. *Pervasive computing and communications, 2004. PerCom 2004. proceedings of the second IEEE annual conference on* (pp. 23–30).
Rehrl, K., Bruntsch, S., & Mentz, H.-J. (2007). Assisting multimodal travelers: Design and prototypical implementation of a personal travel companion. *Intelligent Transportation Systems, IEEE Transactions On*, *8*(no 1), 31–42.
Rodriguez-Sanchez, M. C., Martinez-Romo, J., Borromeo, S., & Hernandez-Tamames, J. A. (2013). GAT: Platform for Automatic Context-Aware Mobile Services for M-Tourism. *Expert Systems with Applications*.
Rodriguez-Sanchez, M. C., Moreno-Alvarez, M. A., Martin, E., Borromeo, S., & Hernandez-Tamames, J. A. (2014). Accessible smartphones for blind users: A case study for a wayfinding system. *Expert Systems with Applications*, *41*(16), 7210–7222.
Salmeron, J. L. (2012). Fuzzy cognitive maps for artificial emotions forecasting. *Applied Soft Computing*, *12*(12), 3704–3710.
Sheng, Z., Yang, S., Yu, Y., Vasilakos, A., Mccann, J., & Leung, K. (2013). A survey on the ietf protocol suite for the internet of things: Standards, challenges, and opportunities Wireless Communications. *IEEE*, *20*(6), 91–98.
Su, K., Li, J., & Fu, H. (2011). Smart city and the applications. *Electronics, Communications and Control (ICECC), 2011 international conference on* (pp. 1028–1031).
Swierenga, S. J., Propst, D. B., Ismirle, J., Figlan, C., & Coursaris, C. K. (2014). *Mobile design usability guidelines for outdoor recreation and tourism*. *HCI in business*, . Springer International Publishing371–378.
T-GuIDE, Tourist Guides for People with Intellectual and Learning Difficulties in Europe Last access (January 2015) http://www.t-guide.eu/?i=t-guide.
Tesoriero, R., Gallud, J. A., Lozano, M., & Penichet, V. M. R. (2008). Using active and passive RFID technology to support indoor location-aware systems. *IEEE Transactions on Consumer Electronics*, *54*(2), 578–583.
Tinwala, H., & MacKenzie, I. S. (2010). Eyes-free text entry with error correction on touchscreen mobile devices. *Proc. NordiCHI '10* (pp. 511–520).
Westerbeek, H., & Maes, A. (2013). Route external and route internal landmarks in route descriptions: Effects of route length and map design. *Applied Cognitive Psychology*, *27*(3), 297–305.
Yayan, U., Akar, B., Inan, F., & Yazici, A. (2014). Development of indoor navigation software for intelligent wheelchair. *Innovations in intelligent systems and applications (INISTA) proceedings, 2014 IEEE international symposium on* (pp. 325–329).
Yuen, J. K. K., Lee, E. W., & Lam, W. W. H. (2014). An intelligence-based route choice model for pedestrian flow in a transportation station. *Applied Soft Computing*, *24*, 31–39.
van Setten, M., Pokraev, S., & Koolwaaij, J. (2004). Context-Aware recommendations in the mobile tourist application COMPASS. In W. Nejdl, & P. De Bra (Eds.), *AH 2004, LNCS 3137*. Springer-Verlag.

Cristina Rodriguez-Sanchez, Madrid, Spain, 1982. M.Sc. in Computer Science (2005) and PhD in Computer Engineering and New Technologies (2009) from the Universidad Rey Juan Carlos. She became in expertise about Internet of Things with the PhD. Since 2006, she has been with the Area of Electronic Technology at the Universidad Rey Juan Carlos, Madrid, Spain. Besides, she coordinates and participates in national projects on Accessibility, Navigation, Wireless System and Monitoring. She received the 2013 MIT TR35 Award and the 2014 European Satellite Navigation award related to those projects.

Juan Martinez-Romo, Madrid, Spain, 1980. received the Ph.D. degree in Computer Science at UNED in Madrid, Spain at 2010. From 2005 to 2007, he developed his research activity at the Grupo de Sistemas y Comunicaciones at URJC. He is currently Associate Professor at the UNED in Madrid, Spain, and belongs to the NLP & IR Group of this University. His research interests include web information retrieval, natural language processing, mobile technologies, biomedicine, and web spam.